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ACCUMULATORS AND BATTERIES

THE Do It Yourself SERIES

ACCUMULATORS
AND
BATTERIES

A GUIDE TO THEIR
WORKING AND MAINTENANCE

BY
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LONDON
W. FOULSHAM AND CO., LTD.
10 & 11 RED LION COURT, FLEET ST., E.C.4

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MADE AND PRINTED IN GREAT BRITAIN BY PURNELL AND SONS
PAULTON (SOMERSET) AND LONDON

PREFACE

In these days of popular motoring and wireless, many people with little or no technical knowledge find themselves saddled with the task of looking after and maintaining, in a healthy condition, an electric accumulator. Too often this maintenance consists, in the case of a car, of pulling down the "charge" switch when running, and leaving the rest to the garage mechanic; while in the case of a wireless set it means a more or less regular visit to the shop where the battery is charged. Many of us sigh for the necessary knowledge which would enable us to look after our batteries ourselves, since we are certain that they never last as long as they should.

There are many books from which we could get the theory of the accumulator, and many manufacturers' pamphlets which tell us how to look after their own particular products; but these, however, often assume a working knowledge of electrical terms such as ampère, volt, watt, etc., which leave us as ignorant after reading them as we were before. It would be comparatively easy to frame a list of rules which would, if strictly adhered to, enable us to get good results out of our accumulators, but this would not help us to understand the accumulator; and the carrying out of routine jobs which we do not understand is apt to become rather an irksome business. It is my purpose, in this book, to help you to get good results from your accumulators and batteries by *understanding* their needs.

J.A.F.

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ACCUMULATORS
AND
BATTERIES

CHAPTER I

ELECTRIC CURRENTS

WHY THEY TRAVEL AND HOW THEY ARE MEASURED

Now we all know that an accumulator is a device for supplying an electric current, so the best starting point will be to say what is meant by an electric current, or better still to try to explain the term "Electricity". To answer the question "What is electricity?" is impossible—nobody knows. We do not know what electricity is, but we do know how it behaves and what it does.

It has been known from the earliest times that amber, when rubbed with wool or fur, becomes possessed of the property of attracting small fragments of wood, paper, etc. Later it was observed that this property was not confined to amber, but was common to sulphur, glass (when rubbed with silk), ebonite, and in fact any substance to a greater or lesser degree. These substances were said to behave like amber or to be "electrified," since "elektron" is the Greek for amber. They were supposed to be permeated by something which was called electricity, they were said to be *charged* with electricity.

Now ebonite will retain its charge even if we hold the ebonite in our hand. If, however, a rod of brass is rubbed, no charge can be detected unless we fit it with an ebonite or glass handle. The electricity —whatever it is—will not stay on the brass if it is in contact with our hands. Suppose we take our brass rod fitted with an ebonite handle, rub it with wool (flannel) and charge it, it will attract small pieces of paper. Now let us touch the rod with our finger—the brass has lost its electric properties. The electricity has passed through our fingers and disappeared. We say it has run to earth through our body. This passage of electricity from the brass to earth, through our body, is an electric current. It is, of course, only instantaneous and we cannot feel it, but it is there.

There is practical evidence of the existence of this current. You have probably noticed at some time or another that all steam wagons with rubber tyres have a small piece of chain hanging underneath them so as to just touch the ground. If this chain were not there, the friction of the dry steam, as it rushes out of the safety valve, would charge the wagon with electricity which could not "run to earth", because rubber is one of those substances through which electricity will not travel. If left for some time, the wagon accumulates a very heavy charge of electricity, and if the driver steps from the wagon and so connects the wagon to earth, this charge runs through him and gives him a very nasty shock—but, luckily for him, of extremely short duration.

We have just referred to rubber as being one of the substances through which electricity will not pass. There are many such substances—ebonite, paper, cotton, sulphur, glass, wood, porcelain, gutta-percha, silk, and, in fact, most non-metallic substances. They are known as "insulators". On the other hand, there are many substances—copper, gold, silver platinum, lead, brass and all metals, through which electricity can pass with the utmost ease. These are called "conductors". A noteworthy case of a non-metallic conductor is carbon. Impure water is a conductor, while absolutely pure water is an insulator. Since we rarely, if ever, get absolutely pure water, the presence of moisture on an insulator renders it (the insulator) conducting.

We have seen how the charge on an insulated brass rod, *i.e.* a brass rod with an insulating handle—which is electricity at rest (static electricity)—can be made to move by touching the brass rod with a conductor—*viz.* the fingers. We can produce by this means an instantaneous electric current. The question we now have to ask ourselves is, "Why does the electricity flow from the brass to the earth?" At this point we may find it helpful to compare the properties of electricity with those of a fluid—say water.

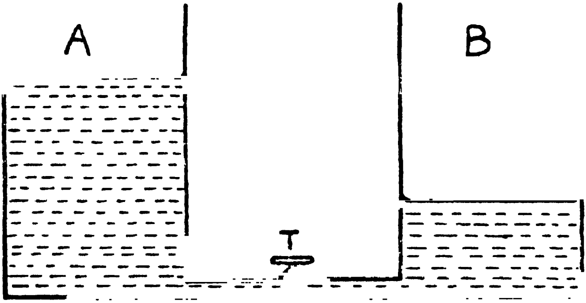

FIG. 1

Suppose we have two tanks of water—A and B (Fig. 1)—and that the level of water in A is higher than the level in B. If the tap T is closed, no water will flow between the two tanks. If the water in A and B be compared with electricity, then T would be an insulator. If T is now opened (A and B joined by a conductor) the water will flow from A to B until the levels (pressures) are the same in each tank. This is precisely what happens in our electrical case. If two conductors which are insulated are filled (charged) with electricity to different levels, and they are joined by means of a conductor (a copper wire), electricity will flow along the wire until the levels of electricity are the same. Since electricity travels very rapidly, this adjustment of electric level or pressure, takes only a fraction of a second. We do not speak, however, of electric pressure, but of electric *potential.* Thus electricity will flow between two points if those two points are joined by a conductor, and if there is a difference of *potential* (pressure) between them.

This flow is independent of the *amount* of electricity present; it depends solely on the difference of potential. We may explain this by again referring to our water tanks. Suppose that the tank A is much smaller than the tank B (Fig. 2) and that the level in A is again higher than the level in B; when T is opened, water will flow from A to B until the *levels* in A and B are the same in spite of the fact that A holds much less water than B. The direction of the flow only depends on the difference of level or of pressure, and not on the amount of water present.

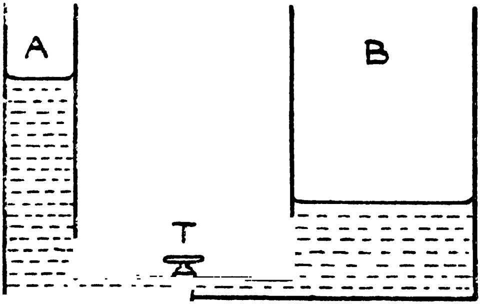

FIG. 2

We could measure the difference in pressure between A and B in terms of the difference in level between

A and B. For instance, we speak of a "head" of 100 ft. of water when the difference in level is 100 ft. We cannot measure the pressure of electricity in these terms; we must have an electrical unit of pressure—or of *potential*, as we have decided to call it. This unit is the *volt*, named after Volta, an early experimenter and investigator of the properties of electric currents. The actual definition of the volt is beyond the scope of this book. Suffice it to say that two points are said to have a potential difference of one volt when certain standard conditions are satisfied. What is important to us is, that the volt is a unit of electric pressure.

It seems that we have wandered from accumulators somewhat, but we must remember that the study of accumulators is bound up in the study of electricity, and we must master certain basic facts before we can understand and explain their peculiarities. We must walk before we can run. We are, however, approaching an explanation of the function of an accumulator.

A brief instantaneous electric current, such as we have been considering, is of very little use to us. For instance, a six-volt electric bulb requires that the electric pressure or potential across its filament shall be six volts. If we connect such a bulb across two charged conductors whose potential difference is six volts, the pressure is so soon equalised that the filament does not get time to get warm, and the bulb does not light. In order to light the bulb, we must *maintain* a potential difference of six volts across the filament. We must find a means of supplying electricity to one of the conductors so that this pressure is kept at six volts, and a current is constantly passed through the lamp filament, which then becomes white-hot (heat is always produced when an electric current passes through a conductor).

The first men who discovered means by which conductors could be *maintained* at different potentials, were Galvani and Volta—two Italian scientists.

Volta showed that when a plate of zinc and one of copper were placed in a vessel containing dilute sulphuric acid (oil of vitriol), there was a difference of potential between them; and further, that when these plates were connected by means of a wire, this potential difference, although slightly lowered, was maintained so that an electric current flowed continuously through the wire. Such an arrangement is known as a Voltaic *cell* (Fig. 3). It was found that the copper was at a slightly higher potential than the zinc—the current therefore flows from the copper to the zinc, and the copper is known as the positive (plus or +) plate of the cell, and the zinc as the negative (minus or —) plate of the cell. The actual potential difference between the plates of such a cell is rather small—about 1 to 1½ volts—and in Volta's time this potential difference was rather difficult to detect.

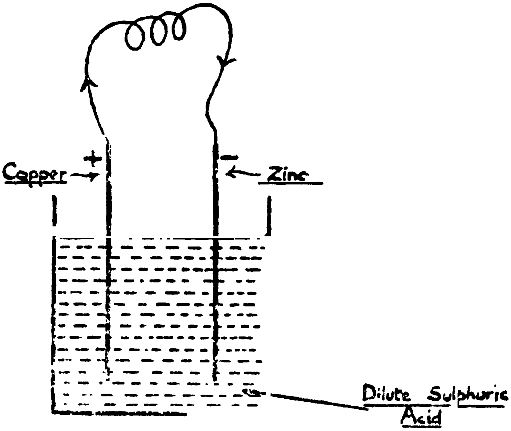

FIG. 3

THE SIMPLE VOLTAIC CELL

Volta's actual arrangement is shown in Fig. 4. He arranged a pile of copper and zinc plates thus:—starting with a copper plate he put on top of this a piece of cloth soaked in sulphuric acid, then a zinc plate, next a copper one and so on, forming a number or *battery* of cells in *series*; *i.e.* the positive (copper) of one cell was connected to the negative (zinc) of the next (Fig. 5). The potential difference across the ends of such an arrangement is equal to the sum of the potential differences across each cell separately, since if we refer again to the diagram, Fig. 5, we see that there is a potential difference (pressure) of about 1½ volts between A and B, and between C and D; but B and C are at the same potential, so that the potential difference between A and D is three volts.

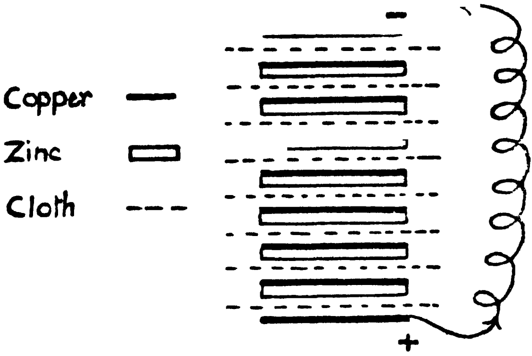

FIG. 4

VOLTA'S PILE

We often hear people speak of the E.M.F. or *electromotive force* of a battery. This is really the potential difference between the plates when the cell is not supplying current or, as we say, "on open circuit". When the cell starts to supply current, this potential difference decreases.

The cell just described is a primary cell—*i.e.* it produces current itself and requires no attention other than replacing the acid and plates occasionally. You might then very well ask "Why have accumulators?" One of the most important reasons is that the voltaic cell has a very high "internal resistance." The current in a circuit not only passes through the wire but through the cell as well; and, if it is difficult for the current to get through the cell—*i.e.* if the internal resistance is high—we do not get much available current in the external circuit for the lamps or bell or whatever it is we wish to work; but the internal resistance of an accumulator is very small.

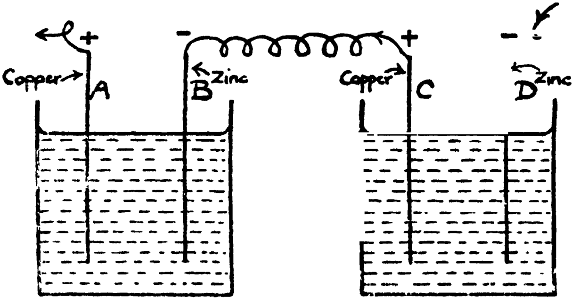

FIG. 5

CELLS IN SERIES

We now have investigated the conditions under which an electric current will flow—there must be an electric pressure (measured in volts) to drive it, but we have not yet said how it is measured. Obviously we cannot measure current in volts any more than we could measure the amount of water flowing in a pipe, in pounds per square inch. The unit of current universally used is the *ampère*, and here again—as with the volt—we can only say that a current of one ampère is one that satisfies certain standard specifications.

The potential difference (P.D.) between two points

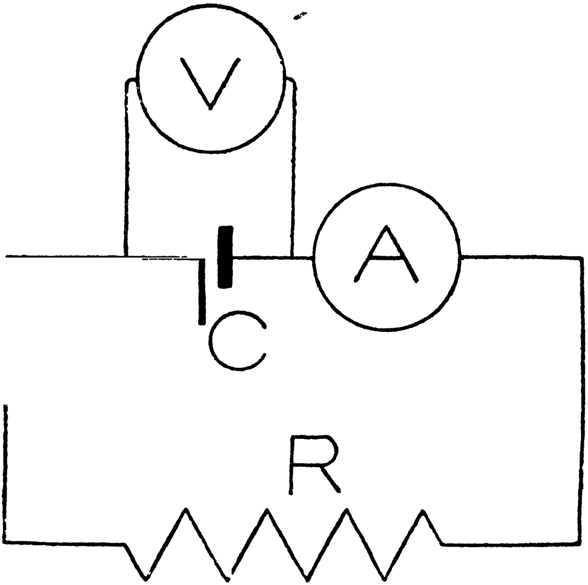

Fig. 6

Use of Voltmeter and Ammeter to Measure the E.M.F. and the Current in a circuit

is measured in volts by means of a *voltmeter*, and the current through a wire is measured in ampères (amps) by means of an ampère-meter or *ammeter*.

A voltmeter is an instrument of high resistance, so that, when it is connected between two points, hardly any current flows, and the potential difference between the two points does not fall.

An ammeter is an instrument of low resistance, since it must be put in *series* with the circuit. If it were of high resistance it would itself alter the current somewhat.

Figure 6 shows how a voltmeter (V) and an ammeter (A) should be used to measure the potential difference across the plates of a cell (C) and the current it is supplying to an external circuit (R). The long thin line and the short thick line used to represent the cell (C) is a conventional way of drawing a cell. We shall use this method of representing a cell in any future circuit diagrams we may wish to draw.

We have seen how a primary cell will produce an electric current, but is unsatisfactory for practical use where fairly large and constant currents are required. The only other means of producing an electric current is by means of a dynamo. A dynamo, however, requires to be driven by a steam or oil engine, by water power or by a wind mill, so that it is only used for production of electricity on a large scale (a motor car dynamo is, of course, an exception). Some other device is necessary which will give the wireless enthusiast and other people who want low voltage current, a steady and reliable source of supply. This need is satisfied by the accumulator.

CHAPTER II

PRIMARY CELLS AND BATTERIES

In spite of the fact that there are many objections to the primary cell as a source of current, it is still used a great deal in circuits where the current required is either very small, or intermittent.

In its original form the Voltaic cell is of no practical use. The chief source of trouble is due to the collection of bubbles of a gas (hydrogen) on the copper plate while the cell is working. When the cell has been supplying current for a short time, these bubbles cover the copper plate and insulate it from the dilute sulphuric acid—or, as we say, the "electrolyte" of the cell. This means that there is not a complete circuit for the current, which rapidly dies away to almost nothing. The prevention of the current flow by these bubbles is said to be due to the "polarisation" of the cell, and all modern primary cells have been designed to prevent this polarisation; this is usually done by placing in the cell a substance which will combine with, and thus absorb the gas as it is produced. A substance introduced into a cell to prevent polarisation is known as a "depolariser".

Several types of primary cell have as their basis the simple Voltaic cell; that is, they consist of a zinc and a copper or carbon plate, with a "porous pot" containing the depolariser round the latter, all immersed in sulphuric acid. The porous pot is an unglazed jar through which the sulphuric acid can penetrate, but which will keep the depolariser round the copper or carbon plate where it is required.

These cells are fairly efficient, but it is difficult to prevent chemical action going on in the cell while it is not working; they also give off rather objectionable fumes in some cases, and are therefore not very popular. There are, however, other ways of making a simple primary cell, besides by placing a zinc and a copper plate in sulphuric acid.

If we place a zinc and a carbon rod in a solution of sal ammoniac (ammonium chloride), and join them by means of a copper wire, an electric current flows from the carbon plate to the zinc rod. The carbon plate is maintained at a higher potential than the zinc, so that the carbon is the positive plate of the cell, and the zinc the negative. If we connected an ammeter, or current measurer, in series with the cell, we should observe that the current would at first be about ½ ampère, but in a very short time this would fall to about 1/20th of an ampère, or even less. This is due to polarisation of the cell, so that although this cell is slightly better than the first, in that it gives off no objectionable fumes, it is still useless as a source of steady current, however small. In order that the cell should maintain the current flow, we must introduce into the cell a "depolariser", and this is done in the Leclanché cell, the most common of all primary cells.

The Leclanché cell consists, in its essentials, of a carbon plate and a zinc rod immersed in sal ammoniac solution, the carbon plate being surrounded by manganese dioxide—a black powder which acts as a depolariser; it gives up some of its oxygen to the hydrogen, and turns the latter into water. There are two types in common use to-day, the "wet" cell and the so-called "dry" cell. The "wet" Leclanché cell usually consists of a glass jar in which is placed a zinc rod, and a porous pot, which contains the carbon plate surrounded by a mixture of manganese dioxide and coke (Fig. 7). The coke is mixed with the manganese dioxide in order to make a porous mixture through which the sal ammoniac solution can easily percolate. The manganese dioxide mixture is placed in a porous pot because its presence is only required round the carbon plate—in smaller wet cells, a small sack of canvas is used to keep the manganese dioxide round the carbon. The top of the porous pot is sealed with pitch which is also painted down the sides of the pot for about 1-in.–1½in. to prevent the electrolyte (*i.e.* the ammonium chloride solution) from "creeping". When the sal ammoniac solution is poured into this cell, it diffuses through the porous pot and the manganese dioxide mixture, and reaches the carbon plate. A hole is left in the top of the pitch to allow of the easy escape of the air in the porous pot when it is first inserted in the sal ammoniac solution. If we joined the "terminals" (*i.e.* the

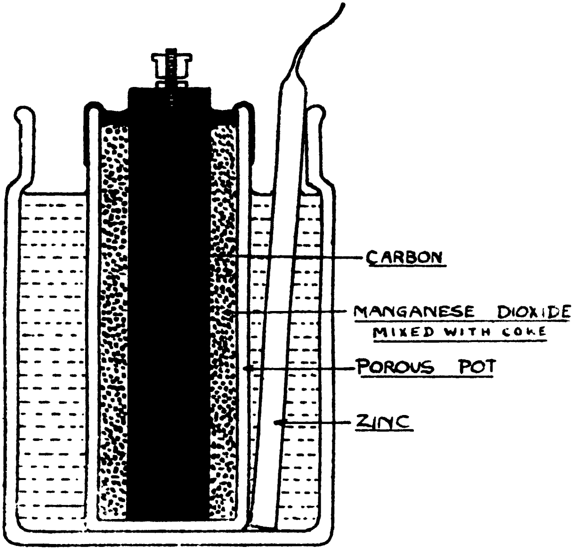

FIG. 7

THE LECLANCHÉ CELL

plates of this cell) to an ammeter, we should find that the current would be maintained at a fairly high level in a much better way than was the case with the simple cell. The current, however, does fall away because the depolarising action is slow; if it is disconnected, however, the cell soon recovers, and it is on this account that it is used so extensively for intermittent current work, such as the operation of electric bells. The electromotive force or E.M.F., of this cell, is about 1·5 volts.

The internal resistance of the Leclanché cell described is rather high, so that the maximum current obtainable is small. We can decrease the internal resistance by using a plate of zinc wrapped round the porous pot instead of having a zinc rod. This is rarely done since, when the cell is working, the zinc is consumed; and if it is in the form of a thin plate, it is eaten away so rapidly that replacements have to be made frequently.

When these cells are once set up, they require hardly any attention; and to set them up, we have only to place our porous pot, containing the carbon plate and manganese dioxide, together with a zinc rod, in a solution of sal ammoniac. The correct proportions for the "electrolyte" are 1 lb. of sal ammoniac to 1 gallon of water. Of course, if our cell is, say, a 1 pint cell, we need only 2 ozs. of sal ammoniac.

We can make the sal ammoniac dissolve quickly and easily by gently warming the water. Having set the cell up, we should inspect it periodically—about once a fortnight—when water should be added to make up losses due to evaporation; tap water will do for this. If the cell is kept in a warm place, it should be inspected more frequently. After the cell has been in use for some time, crystals may have formed on the zinc rod and the porous pot. These may be scraped off the former and scrubbed off the latter with a stiff brush. Since the zinc is consumed when the cell is working, the zinc rod becomes very thin in time, and must be replaced.

Fresh solution must also be placed in the cell now and again. There is no definite interval of time which should elapse before the solution is renewed; it should be done when, with everything clean in the cell, it only gives a feeble current. Similarly the life of the porous pot depends upon the conditions under which the cell is used. If it is kept free of crystals and is allowed to drain before each fresh supply of solution is added, it should last several years. When, however, we get a feeble current with fresh solution and clean zinc, then the porous pot must be at fault, and should be replaced by a new one.

By far the most common form of Leclanché cell in use to-day is the so-called "dry" cell; flash lamp batteries and wireless high tension batteries consist of groups of these cells, which are not really "dry". They are merely "unspillable" Leclanchés. They consist of a carbon rod (the positive terminal) surrounded by a paste of manganese dioxide, which is in turn surrounded by a layer of sawdust or plaster of paris saturated with sal ammoniac, which is damp. The whole is placed in a zinc case which forms the negative terminal of the cell. This cell is not therefore a "dry" cell; and in fact, if it were absolutely dry, it would not work. When such a cell has been in use some time, the zinc case is eaten away and the cell becomes dry and useless. Nothing can then be done to revive the cell. A dry cell should not be purchased a long time before it is required, since the paste does dry out in time, and the useful life of the cell is shortened.

Since the carbon and the zinc are very close to each other in the dry cell, its internal resistance is rather small, so that the current available is rather high. On this account its terminals should not be connected directly together or, as we say, the cell must not be "short-circuited" or shorted. If this is done, a large current will flow, and under these conditions the life of the cell is very much reduced.

In a battery such as a wireless battery, which consists of a number of dry cells in series, it sometimes happens that some of the cells become worn out before the others. We can detect this by connecting a lamp or a voltmeter across successive cells or groups of cells (Fig. 8) and noting the effect. The cells which are no longer any use may be "shortened" out, by connecting a wire across them so that they are no longer in the circuit. The rest of the cells can then be used until they, too, are fully discharged.

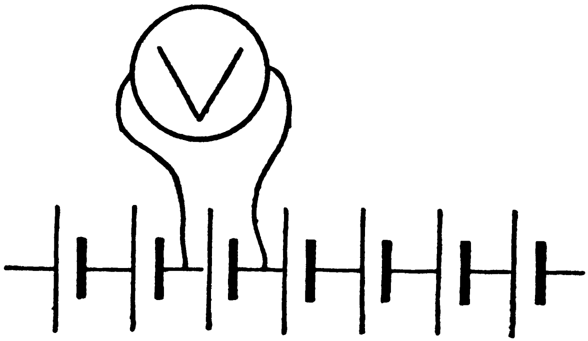

FIG. 8

THE USE OF A VOLTMETER TO TEST ONE OF A NUMBER OF CELLS CONNECTED IN SERIES

There are many so-called "dodges" for resuscitating dry batteries, such as warming them and so on. These dodges may, in isolated cases, increase the efficiency of the cell for a very short time, but there is no method which will give a dry battery a new lease of life when it has once ceased to deliver a useful current. It is obvious that if all the chemical energy of the cell has been used up, it is of no further use.

CHAPTER III

THE STORAGE OF ELECTRICITY

We have seen how a primary cell can be used for the production of small currents and how, in the course of using the cell, some substance is used up chemically, in the production of the current. This is rather expensive. The solution of the difficulty of providing a fairly large, low-voltage current was supplied by Gaston Planté in 1859, when he succeeded in making a cell which would store up energy passed in as an electric current, and which would subsequently give up this energy as an electric current when required. Such a cell is known as a "storage" cell, an accumulator or a "secondary" cell. The first two of these names are rather bad ones, as they tend to make us think that they actually store up, or accumulate, electrical energy. What really happens is, that the electrical energy passed into the cell becomes converted into, and stored as, chemical energy, which can be released, when required as electrical energy, in the form of an electric current.

A simple form of secondary cell may be made in the following way:—two clean lead plates are immersed in dilute sulphuric acid so that they do not touch each other. They are then connected to a source of electric current, say a dynamo, and a current is passed through the cell. Bubbles of hydrogen will then rise from the plate connected to the negative terminal of the dynamo, while the plate connected to the positive terminal of the current supply, slowly changes its colour until it is a dark brown. On disconnecting the cell from the dynamo, and joining the plates with a wire, we find that an electric current flows from the brown plate to the other plate which has turned a dull slate colour. Thus we have a source of current of which the positive terminal is the brown plate and the negative terminal, the grey one. While these two plates are connected, the current will continue to flow until all the brown colouration has disappeared from the positive plate. In order to use the cell again, we must pass an electric current through it as before; or, as we say, it must be "charged" again, or recharged. When we take current *from* the cell we say that the cell is discharging.

The chemical actions which go on inside an accumulator are very involved, but we can get a fair idea of what happens without going very deeply into them. The process by which the cell originally becomes charged is not important. The positive plate becomes brown owing to the fact that the lead on the surface combines with oxygen in the acid, under the influence of the electric current, to form lead peroxide, which is brown. We will suppose that the cell is charged and ready for use. When the plates are connected, the sulphuric acid reacts with this brown substance on the positive plate, forming lead sulphate and water; the latter being produced by the combination of the hydrogen in the acid with the oxygen in the lead peroxide. Thus, when the cell is discharging, the following action takes place at the positive plate:—

Lead peroxide + sulphuric acid = Lead sulphate + water.

At the negative plate, the acid acts on the lead to form lead sulphate, the hydrogen produced being "oxidised" (*i.e.* combined with oxygen) by the internal actions of the cell, to water. This action may be represented thus:—

Lead + sulphuric acid = lead sulphate + water.

It will be noticed that, in each case, the "electrolyte" of the cell, *i.e.* the sulphuric acid, becomes converted into, or rather replaced by, water.

Now sulphuric acid is a denser liquid than water —that is, if we took equal volumes of acid and water, the sulphuric acid would be heavier. The ratio of the weights of equal volumes of any substance and water, is known as the "specific gravity" of that substance. Thus, when we say that the specific gravity (sp. gr.) of copper is 8·9, we mean that, if we weighed equal volumes of copper and water, we should find that the copper would be 8·9 times as heavy as the water.

Pure sulphuric acid has a specific gravity of 1·840; *i.e.* since a cubic foot of water weighs 1,000 ounces, a cubic foot of sulphuric acid would weigh 1,840 ounces. The electrician does not usually speak of a specific gravity of 1·840; he drops the decimal point and calls it 1,840°, which means, 1,840 degrees specific gravity. Thus water has a specific gravity of 1,000°.

Now to return to our simple accumulator, when the cell is discharging, *i.e.* delivering an electric current, the sulphuric acid gradually becomes replaced by water. Thus the specific gravity of the electrolyte gets less as the cell is discharged. This provides us with a means of testing the condition of a cell, and we shall refer to it later.

We will now suppose that the cell is charged up again; the lead sulphate on the positive plate is reconverted into brown lead peroxide, and that on the negative plate is changed back into lead, while the electrolyte becomes a stronger solution of sulphuric acid. Hence the specific gravity of the electrolyte increases when the cell is charged.

An accumulator of the type we have just described, will not supply current for a very long time. We say that its electrical "capacity" is small. The capacity of a cell is measured in ampère-hours, that is the product of the current in ampères and the time for which the cell could supply that current.

Thus if the cell will supply a current of two ampères for 10 hours, then the capacity of that cell is 20 ampère hours. We should find that if a cell were capable of supplying two ampères for 10 hours, it would supply a current of one ampère for more than 20 hours. The more slowly a cell is discharged the more we get from it; or, the greater its capacity. Most accumulators when they are sold are labelled with their capacity, but since the capacity varies with the rate of discharge, what does this mean? Well, the maximum current that can safely be taken from the cell is also given. Suppose this is two ampères, and the rated capacity is 20 ampère hours, then this cell will deliver a current of two ampères for 10 hours. With slower rates of discharge the capacity would be more, and with higher rates, less.

Accumulators are sometimes classified by their "ignition capacity". This means the capacity on an intermittent discharge, such as would be required by an electric bell or the ignition coil of a car. Usually this is twice the continuous current capacity of the cell. The continuous current capacity of a cell is called its "actual capacity".

We never discharge an accumulator until it can supply no more current; if it is fully discharged the life of the plates is very considerably reduced. The capacity of a cell, therefore, is the amount of electricity, measured in ampère-hours, that it will deliver at its maximum rate of discharge, before the potential difference between the plates has reached the safe minimum. The maximum potenial difference between the plates, when the cell is fully charged, is about 2·20 volts; this rapidly falls, when the cell is in use, to just over two volts. As the cell continues to be discharged, the potential difference between the plates gradually falls still lower, and we should stop taking current from the cell when this potential difference is down to 1·85 volt.

We have said that the capacity of the simple accumulator, which has just been described, is very small. This means that it will only supply a small current for a very short time before the safe limit is reached. Now when this simple accumulator is charged, the positive plate becomes coated with lead peroxide, and the negative plate turns slate coloured, while its surface feels smoother than before, due to the formation of "spongy lead" on its surface. These surface layers, formed by the action of the charging current, are termed "active material" and the capacity of the cell depends upon the current and upon the area of active material presented to the action of the acid. It is an advantage to encourage the formation of "spongy lead" on the negative plate, because its surface area is so large. Lack of capacity is not, however, the only drawback to this accumulator. The way in which the plates are first formed—from pure lead—is very expensive. A great deal of current has to be used before the negative plate is sufficiently spongy, and before there is sufficient lead peroxide on the positive plate. The process is also a very lengthy one.

Most of the modern developments in accumulator design and manufacture are the result of efforts to hasten the formation of the plates, and to increase their capacity without unduly increasing the weight of the cell. It is obvious that we could increase the amount of active material in our simple accumulator by having very large plates, or a large number of positive and negative plates in each cell; but since, in each case, there is only a thin coating of active material, most of the weight of the cell is due to the inactive lead inside the plates.

The simplest method of accelerating the formation of the plates is to apply the active material to the plates before they are put in the cell. This method was devised by Faure. In early plates of this type, some difficulty was experienced in getting the material which was applied in the form of a paste, to adhere to the lead plates. This difficulty was eventually overcome by applying the paste to a grid of cast lead; the spaces in the grid being filled with the paste (Fig. 9). This method of making the plates may be used for both positive and negative plates. Faure filled the spaces in the grids with a paste made of red lead and sulphuric acid. When plates of this type are immersed in sulphuric acid and a current is passed between them, the red lead on the positive plate becomes brown (lead peroxide being formed) while that on the negative plate is reduced to pure lead in the spongy form. In this way the plates are made very porous, and present a very large area of active material to the acid. Hence they have a large capacity. It will also be noticed that the first charge produces the requisite amount of active material, and in this way the lengthy and costly process of "forming" the plates is eliminated.

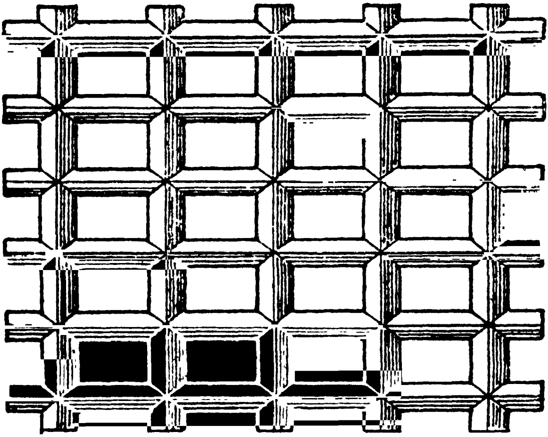

FIG. 9

PART OF THE GRID OF AN ACCUMULATOR PLATE

The paste and grid plate as devised by Faure is however, not so durable as the formed plate of

Planté. Both types of plate are in fairly wide use to-day. Many manufacturers using formed plates for the positive, and paste plates for the negative elements of their cells. The treatment of accumulators is the same whether the plates are of the "formed" or of the "paste" type.

CHAPTER IV

TYPES OF ACCUMULATORS

THEIR DESIGN AND CONSTRUCTION

Accumulators are used nowadays for so many different kinds of work that it would be impossible to consider each type separately. It is inevitable that accumulators for special purposes have been developed along lines which will give the best results in the conditions under which they are to be used. We can conveniently divide accumulators into two types:—

1. The portable type, such as we use in motor cars, wireless sets and so on; these are usually in celluloid, ebonite, or glass containers.
2. The stationary type of cell which is used in house lighting and power-station batteries.

We will deal with the portable cells first, and see what characteristics they have.

A portable battery may be required for supplying a fairly large current for a fairly short time, as in the case of a car battery, or it may be required to deliver a small or intermittent current. In the latter case, since the current is small, it takes a long time for the cell to become discharged, so that it must be of the type which can be left a long time between charges. In order to understand the differences in design in these two cases, we must first look into some of the ailments from which batteries are likely to suffer.

One of the most serious causes of bad working on the part of a battery is excessive "sulphation".

Now we have seen that, in the normal working of a secondary cell, while it is producing current, active material is being changed into lead sulphate. This process is "normal sulphation". If, however, a battery is not worked sufficiently, particularly when it is new, the lead is attacked by the acid, and lead sulphate is again produced, giving rise to "abnormal sulphation."

This sulphate, which is deposited in the form of white crystals on the plates, affects the state of the spongy lead on the negative plates, rendering it impervious to the acid; and if it does become impervious to the acid, the cell loses its capacity. The fact that the plates are porous, when in working order, means that the acid is in contact with a huge area of active material; and if this porous condition is upset, then the capacity of the cell is very materially decreased. The positive plates are injured by the sulphation setting up an increase in bulk, which imposes irregular strains in the plate. A cell for slow-discharge work must, therefore, be one in which the risk of sulphation is a minimum, since such cells have very long periods of comparative inactivity during which sulphation may be set up.

It is found that the best type of cell for slow discharge work is one which has very thick plates. The development of the dull-emitter valve for wireless work led to the demand for a cell which would come to no harm if left for long periods between charging, and for this reason thick plate accumulators are now very popular.

Now if a thick plate cell withstands sulphation, why is it not also used in batteries which have to deliver large currents? The reason is that the chemical actions which go on in the innermost parts of a thick plate are not so rapid as those which occur at the surface. The outside surface constantly has a supply of fresh acid in contact with it, while it takes some time to replace that in the pores of the plate when it has been used up. It is only with slow rates of working that thick plates are worked evenly throughout. If the plates are worked unevenly—that is, if the cell is called upon to deliver a very large current—they become

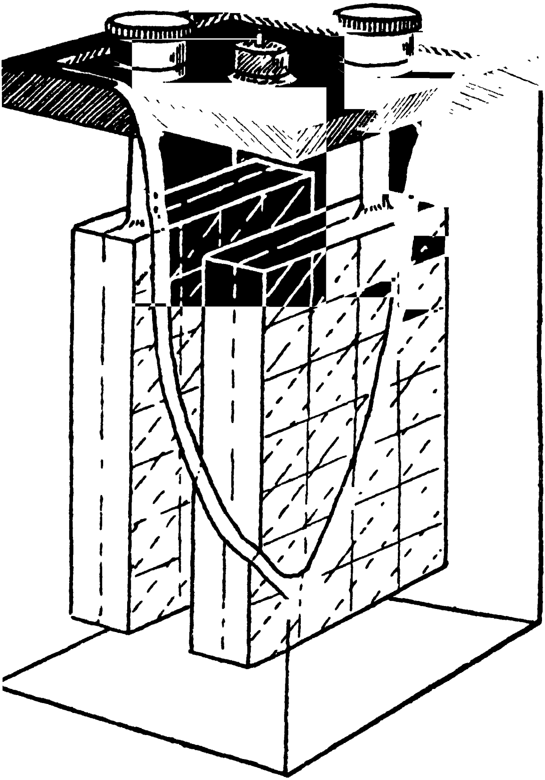

FIG. 10

A THICK PLATE, SLOW DISCHARGE CELL, WITH CORNER OF GLASS CONTAINER REMOVED FOR ILLUSTRATION subjected to large internal strains, causing them to buckle and to shed their active material. Thus in a cell designed for delivering large currents we find, not a few thick plates, but a large number of thin ones arranged alternately.

Thick plate accumulators, in many cases, only have one positive and one negative plate (Fig. 10) mounted in a glass box. The plates are fitted in the cell so that they are exactly parallel. If they were not exactly parallel, then different parts of the plates would be worked to different extents, and as we have mentioned before, a plate which is worked unevenly becomes distorted and sheds its active material very rapidly.

The plates are kept in position by means of ribs which are cast on the inside of the glass container. The whole cell is closed by a lid of ebonite or some similar substance. Two stout leaden rods, one joined to each plate, pass through this lid, and the terminals of the cell are fitted to these rods. In the middle of the lid is a small hole which can be closed by means of a rubber bung or screw stopper, through which the cell may be filled with acid, or topped up with distilled water.

If the cell has a rubber bung, a small piece of glass tubing is passed through it, so that any gas generated in the cell, when it is working, can escape easily. If a screw stopper is fitted, it will have a small hole in it for a similar purpose. The lid is sealed into the glass box by pitch, Chatterton's compound, or some similar substance. Should it become necessary to remove the plates from the cell, this cement must first be removed by chipping it away—do not attempt to melt it out. The lid can then easily be withdrawn from the case. To reassemble the cell it is only necessary to fit the plates back in their original places, replace the lid, and pour molten pitch, or Chatterton's compound, round the joints. Since it is rarely, if ever, necessary to dismantle one of these cells, it is not a disadvantage to have them sealed up in this way.

The plates in these cells are mounted so that they are about ¾-in. apart. The reason for this is that, should fragments of active material fall off the plates, it is impossible for them to become jammed between the two plates. Should this occur, the cell would discharge itself owing to the fact that it would be "short-circuited". This type of short circuit, occurring inside a cell, is known as an "internal short".

Thin plate accumulators—*i.e.* those designed for the supply of fairly large currents—have many more than two plates. The plates are arranged thus:—the first plate is a negative (grey), the second is a positive (dark brown), the next a negative, and so on alternately, the last plate being a negative. Thus, in such a cell, the number of negative plates is always one more than the number of positive plates. Each positive plate is joined to a lead bar known as the positive bus-bar—the whole assembly being called the "positive group". The negative plates are joined together in a similar way to form the negative group. These groups are so made that, when they are in position, the distance between a negative and the next positive is very small, usually not more than ¼-in.; consequently, unless steps were taken to prevent it, the risk of internal shorting would be high.

It is obvious that, with so many plates, we cannot have them arranged with a ¾-in. space between them, as the cell would be far too cumbersome. In order to keep the plates apart, and to prevent internal shorting, separators are placed between them. These separators are made of corrugated celluloid or ebonite, which is perforated; or of wood specially treated to resist the action of the acid upon it, so that it does not rot. The wood is sufficiently porous to allow of easy diffusion of the acid without having holes bored in it. Wooden separators are made of thin diaphragms of wood, with ribs of the requisite thickness fixed at intervals along their surfaces. When the two groups of plates, together with the separators, are placed in the box, they

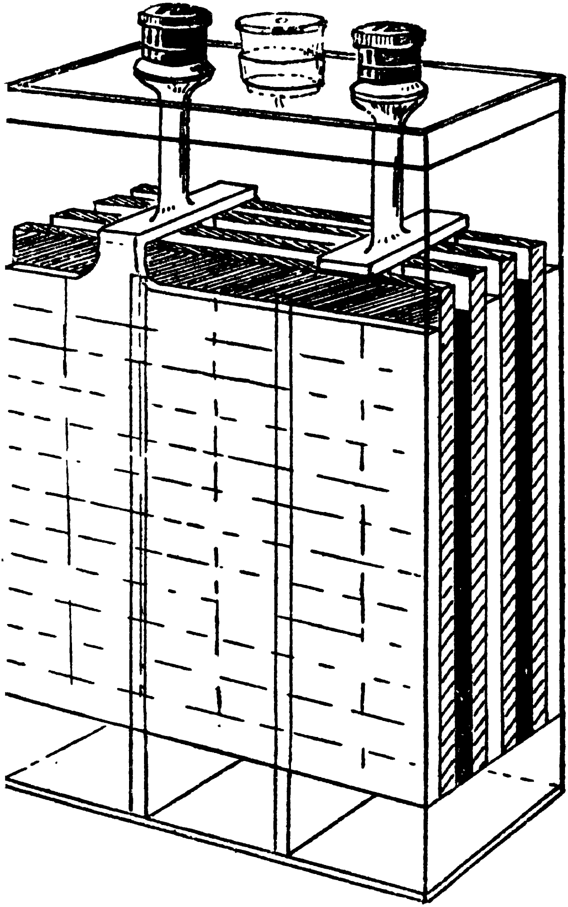

FIG. 11

A THIN PLATE CELL

fit tightly against the sides of the box, so that there is no need for any special arrangement to keep them in position. In order that the acid can circulate freely round the outside negative plates, two ribs are fixed in the box to prevent the whole of their outside surfaces from touching the sides of the box. The accumulator box may be made of glass or of ebonite, and if this is so, the accumulator is sealed by means of pitch, as with the thick plate cell. Thick lead rods, fixed to the bus-bars, stick up through the lid, and the terminals are mounted on them.

Thin plate portable accumulators are often made with celluloid boxes. The lids of these cells are made of celluloid, and are sealed into the box by means of amyl acetate, a substance which will readily dissolve celluloid, and which evaporates very easily. The terminal rods pass through this lid, and the holes through which they pass are sealed, either by means of a rubber bung, or by means of a screwed washer (Fig. 12). In order to remove the lid of an accumulator of this type, a knife should be inserted between the lid and the box at A, and by carefully working the knife round the lid, the sealed joint may be broken and the plates removed. To re-seal the lid in position, a weak solution of celluloid in amyl acetate should be prepared and applied sparingly round the joint. This dissolves off the surface layers of celluloid from the lid and the box, forming a sort of celluloid jelly in the gap between them. On allowing the cell to stand, the amyl acetate evaporates and leaves behind the celluloid, making a perfect joint. It should be borne in mind that, when doing this, too much amyl acetate must not be used, since it will dissolve away the case itself, or at least make it very soft and pliable and cause it to fall out of shape. The vent-plug, in this type of box, is also made of celluloid.

Since it must have a vent for the escape of gases evolved during its operation, the cell cannot be shaken about without danger of the acid spilling.

Now accumulators are used a great deal on aeroplanes, for wireless, and the illumination of the instruments at night. This has led to the development of "unspillable" accumulators.

The earliest form of unspillable cell was filled with glass wool which soaked up the acid and prevented it from shaking about in the cell. Nowadays cells are rendered unspillable by fitting a device, under the vent, which will prevent the acid from reaching it when the cell is shaken. Figure 13 shows such a device. Cells of this type are used extensively for hand-lamps, and other similar work. Recently cells have been made in which the electrolyte is in the form of a jelly, but they only appear to be suitable for circuits in which the current required is very small.

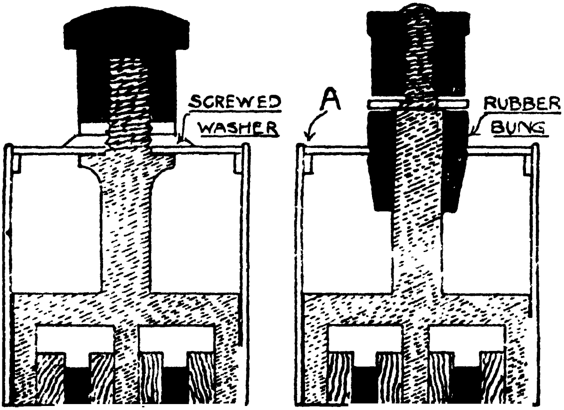

FIG. 12

METHODS OF PASSING THE TERMINAL PILLARS THROUGH THE LIDS OF CELLULOID BOXES

Stationary batteries for house-lighting, and so on, have the same general characteristics as the portable types. They differ only in size and in details of construction. Stationary cells have no lids, the top being left open; or else they are covered by means of sheets of glass, placed loosely over them, to prevent acid splashes from escaping from the cell when bubbles of gas rise to the surface.

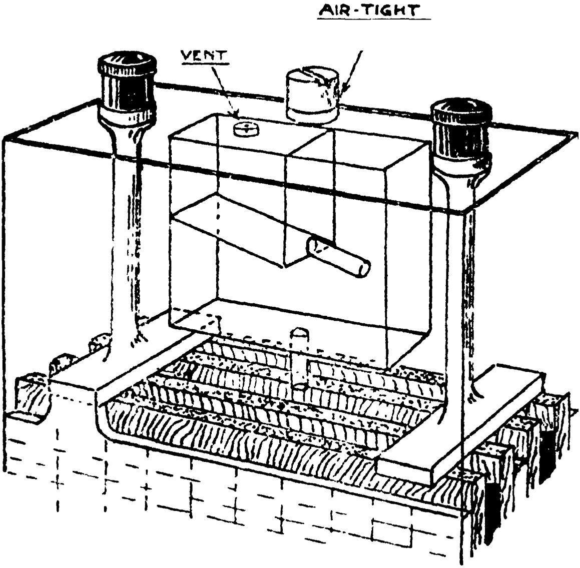

FIG. 13

DIAGRAM SHOWING AN UNSPILLABLE DEVICE FITTED UNDER THE VENT OF AN ACCUMULATOR

The smaller stationary cells always have glass boxes, while the very large ones, such as those used in power stations, and which weigh up to two to three tons each, are mounted in wooden containers lined with lead. The plates of these cells are very thin compared with their area; consequently they can be discharged at a very high rate. Many of them can be discharged completely (*i.e.* down to 1·85 volts each) in 1 hour. This practice however, is not desirable, and it is only resorted to in times of emergency.

CHAPTER V

WIRELESS ACCUMULATORS

SINCE the electric currents (filament current and plate current) required by wireless sets are rather small, the accumulators which are used as the source of supply are chiefly of the thick plate type. The High Tension accumulator will certainly have very thick plates, but many thin plate accumulators are still used for the filament circuits, particularly in multi-valve sets.

The first thing to do, when buying an accumulator for wireless work, is to decide what capacity it must have and how many cells are required. With 2-volt valves we shall only require one cell; with 4-volt valves, two cells connected in series will be required, and so on. In order to fix the capacity of the cell or cells required, we must first find out the total current that the valves will require; this is done by adding together the currents that they take separately. These are usually given in the instructions issued with the valve. If the total current is not more than 1 ampère; then 20 ampère-hour cells will be sufficient; for the supply of currents up to 2 ampères, a 30 ampère-hour cell would be required, and so on. We do not want too small a cell, or it will have to be charged too often; and it must not be too large for, as we know, it is not good for a cell to idle too long and to wait a very long time between charges.

Having purchased our accumulator, it must be given its initial or first charge; but before this can be done, it must be filled with sulphuric acid of the correct specific gravity. If the cells are filled with acid when they are bought, it may be assumed that they have been given their initial charge, and may therefore be used immediately. Accumulator acid can be obtained from most garages (if your wireless dealer does not stock it) and usually has a specific gravity slightly higher than that required by the cell.

The specific gravity of the acid is measured by means of a hydrometer—a little glass float loaded at one end with lead shot, so that it will float upright.

We all know that sea water is denser than fresh water, and that it is easier to swim in the sea owing to the extra "lift" or buoyancy of the sea water. The hydrometer is affected in the same way; the denser the liquid in which it is placed, the higher it floats. The stem of the glass float is graduated so that the point on the scale, *at the surface of the liquid* in which it is placed, shows the specific gravity of that liquid.

Hydrometers for testing the acid of small accumulators, are placed in a glass tube with a rubber bulb at one end,

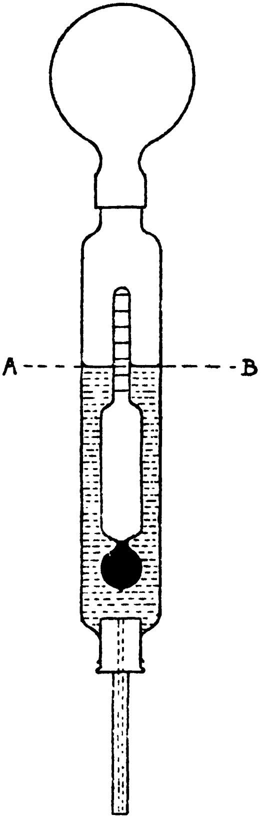

FIG. 14

HYDROMETER FOR TESTING THE ACID IN SMALL ACCUMULATORS. THE READING SHOULD BE TAKEN ON A LEVEL WITH THE LINE A—B, AND NOT WHERE THE LIQUID CURVES UP AND TOUCHES THE GLASS and a thin rubber nozzle at the other (Fig. 14). This nozzle is inserted in the cell through the vent, and the rubber bulb squeezed and then gently released so that acid is drawn up until the hydrometer floats. The specific gravity can then be ascertained.

If the acid purchased for the initial charge is too dense, it must be diluted. Care must be taken that absolutely pure water is used for this purpose. Distilled water—that is water that has been boiled into steam and then recondensed—is the only water that will do for this; it can be obtained from any accumulator dealer, or from a chemist's shop.

It is very unwise to add the water to the acid if the specific gravity of the latter is higher than 1,500°, since a great deal of heat is generated in the process. A small quantity of water should be placed in a stone or glass jar, and the acid slowly poured into it; the whole being gently stirred with a glass rod. Only when the specific gravity of the acid is down to 1,500° or thereabouts, should the water be added. The extent to which the acid must be diluted depends on the type of cell, but as a general rule we may take it that cells of the thin-plate type require acid of 1,250° specific gravity, while thick plate accumulators should be filled with slightly weaker acid than this, having a specific gravity of about 1,230°. If any manufacturer's instructions are issued in this connection, they should be followed implicitly.

Sulphuric acid is an extremely active and dangerous substance, and great care should be taken to prevent it from spilling or splashing over clothes, woodwork or on any metal article. If it is spilled, the corrosive action can be arrested by liberal application of ordinary washing ammonia, or washing soda.

Having prepared sufficient acid of the correct specific gravity, it should be poured into the accumulator until its level in the cell is about ¼-in. to ½-in. above the plates, or until it just reaches the underside of the bus-bars. The cell should then be left for about 12 hours to allow the acid to soak into the plates; after this time has elapsed, more acid must be added to replace that which has been soaked up. The cell is then ready for its initial charge. If the specific gravity of the acid of the cell is tested at this stage, it will be found that it has become slightly too low. This behaviour is quite normal, and is due to the acid attacking the plates. There is no need to add strong acid to bring the specific gravity back to its proper value, as this rectifies itself when the cell is charged.

The cell should next be connected to the source of current from which it is to be charged; the positive terminal of the cell being connected to the positive of the charging source, and the negative terminal to the other. A suitable resistance must be connected in series with the cell, to cut the current down to the required value. It is also wise to connect an ammeter in series with the circuit, so that the exact value of the current can be measured and checked at intervals (see Chapter VII, on Charging). The normal charging current is then passed through the cell for 48 hours, or until the voltage across its terminals remains constant for five successive hourly readings.

During the last part of this charge, the cell will gas freely, and in order to allow the gas evolved to escape easily, the vent plug should be removed. This not only applies to the initial charge, but to every subsequent charge. Since the gas involved is Hydrogen, which is very inflammable, naked flames and lighted cigarettes should be kept away from the accumulator.

The "normal charging rate" of an accumulator depends upon the capacity and type of the cell. A thin plate accumulator can be charged at a much higher rate than a thick plate accumulator of the same capacity, owing to the fact that the plates must be uniformly charged, and the actions within a thick plate are necessarily slow. Usually the normal charging current of a thin plate cell is about

1–10th to 1–15th of its capacity, while that of a thick plate cell is about 1–40th of its capacity.

Should the temperature of the cell during the charge rise above 100° F., the charging current must be cut down slightly, and the charge prolonged to compensate for this.

If the cell has a celluloid box, the acid should be changed at the end of the initial charge, owing to the fact that the acid attacks the celluloid to a slight extent. It is only necessary, after this, to change the acid annually.

It may seem a great waste of time to spend 48 hours on the initial charge and wait for acid to soak in and so on, but so much depends upon the proper treatment of an accumulator when the plates are new, that it does not pay to try to rush the cell into working order.

After the initial charge, the cell is ready for use, and we should endeavour to keep the cell well worked, but not overworked. It is *not economical to keep a cell idle*. The more a cell is worked, the better it will work; it should not, however, be called upon to supply a current of more than $\frac{1}{10}$th of its capacity; if this is done, we may cause the plates to buckle or shed their active material.

The condition of a cell during discharge may be ascertained either by means of a voltmeter or a hydrometer. The latter is preferable. If a voltmeter is used, we should see that the cell is never used after the voltage has fallen to 1·85 volts. If we use a hydrometer, the cell will require charging when the specific gravity of the acid has fallen to 1,110° for thin plates, or to 1,100° for thick plates. The cell should be charged as soon as these minimum values are reached. Excessive sulphation will be set up if we continue to use our accumulators after they have been discharged to the safe limit.

To recharge the cell it should be connected up as for the initial charge. The duration of an ordinary charge is much shorter than that of the initial charge. A cell which has been properly used will be fully charged in 10 to 12 hours if it has thin plates, and in about 20 hours if it has thick plates. The cell is fully charged when the specific gravity of the acid has been brought back to its correct value, or when the voltage of the cell *on charge* is about 2·6—2·7.

While a cell is in use, the level of the electrolyte may fall owing to evaporation. Since it is only water that evaporates, we can make good this loss by adding water until the correct level is restored. Remember that distilled water only must be used for this purpose, and it should be added just before the cell is to be charged, so that the movement of the electrolyte, caused by the gassing of the accumulator when on charge, will thoroughly mix it with the acid already present.

The outside of the cell must always be kept clean and free from water or acid. Moisture on the lid of the accumulator may cause a leakage. The terminals should be periodically cleaned and smeared with pure vaseline; any other grease will not do. This protects them against the corrosive action of any acid that may splash on to them.

If an accumulator is to be left idle for some time, it should be fully charged, emptied of acid, rinsed with distilled water, and finally, filled with distilled water. To prepare the cell for use again, we have only to tip out the water, fill with acid of the correct specific gravity, and place on charge until it gases freely. For periods of two months or less, a cell may be left idle without taking the above precautions, provided that it is charged up about once every fortnight.

The life of an accumulator is an unknown quantity, as so much depends upon the conditions under which it is used; but if it is treated in the manner outlined in this chapter, there is no reason why it should not last four or five years.

CHAPTER VI

CAR ACCUMULATORS

ACCUMULATORS are employed in cars for supplying the current to work the self-starter, the ignition coil (if any) and the lamps. The lamps take a fairly large current, while the self-starter takes a very large one owing to the fact that it is a powerful electric motor, which must be capable of turning the car engine over in the coldest weather. The accumulator for a car must therefore be one which can deliver a large current for a short time (the self-starter is only on for a minute or two at a time). It is not always necessary to have a battery with a large capacity, since the car is usually fitted with a dynamo, by means of which it can be regularly charged. It is obvious what type of battery is required: it must be of the thin plate variety, with a moderate capacity—not more than 40 to 60 ampère-hours. Car accumulators usually have ebonite boxes and consist of two, three or six cells arranged in series, the boxes being made in one block.

When a car is purchased new, the battery must be given its initial charge, and the same care must be taken in this as is necessary when dealing with wireless batteries. Nothing shortens the life of an accumulator more than bad treatment in the early stages of its life. If, as in the case of a wireless battery, it is filled with acid when delivered, it may be assumed that the battery has been given its initial charge, and all we have to do in this case, is to check the acid level, which should be about ¼-in. to ½-in. above the top of the plates. If it is empty, we must make up sufficient acid of the correct specific gravity, fill the cells, leave for 12 hours to allow the plates to become saturated, and add more acid to restore the acid level to its proper height.

The specific gravity of the acid used in car accumulators, is usually higher than that necessary for other types. If no instructions are issued with the cell, it should be filled with acid of specific gravity 1,250° to 1,280°. Having allowed the acid to soak into the plates, the cell is ready for its initial charge. The initial charging rate is often lower than the rate at which it is subsequently to be charged; and as in the case of a wireless battery, it is about $\frac{1}{15}$th of the capacity. The charging should last about 36 to 48 hours, and during the last five hours of the charge, the specific gravity of the electrolyte, and the voltage across the terminals, should be constant.

After this charge, the battery is ready for use; it should be mounted in the car in such a way that it will be easy to test the acid, and to top up with distilled water, when necessary. The battery compartment should be well ventilated, and the battery itself must be firmly seated so that it cannot vibrate and shake about. The terminals should be well greased with vaseline, and the connecting cables must be long enough to reach the terminals without any strain.

When the car is fitted with a dynamo, we must aim at keeping the battery well charged, but we must be careful not to overcharge it. Overcharging results in excessive heating of the battery and evaporation of the electrolyte, and eventually the plates will shed their active material. The specific gravity of the acid should not be higher than about 1,280°, and should not be allowed to fall below 1,150°. If constant "topping up" is required, and the specific gravity of the acid is high, then we are overcharging. If, on the other hand, the specific gravity is generally low, the battery is being undercharged, and either the charging system must be adjusted to charge for longer periods at a higher rate, or the accumulator must be removed from the car and charged in the orthodox manner, as outlined in the next Chapter.

A car accumulator may safely be charged at rates up to one quarter of its capacity provided that it is not allowed to become overcharged.

Owing to the great temperature variations in a car, there is normally considerable evaporation in car batteries so that they should be inspected at least once a fortnight, and distilled water added until the plates are well covered. Any water or acid that is spilt on the lids of the cells should be removed immediately, as the presence of dampness on an insulator renders it conducting, and the cell would therefore discharge itself if the lids were wet.

In winter, car batteries tend to be undercharged, so that, all the time the car is running, we should be charging. In summer, we have to be careful not to overcharge; that is, the "charge" switch should only be on for part of the time the car is running. It is a good plan to work the battery artificially during the summer, by leaving the "parking" lamps or other small lamps burning all night in the garage. The latter must, of course, be well ventilated to minimise the risk of fire.

If at any time during the running of the car the lamps suddenly become very bright, it indicates that the accumulator connections are faulty, and that the dynamo—which must, of course, be of a higher voltage than the accumulator—is supplying current straight to the lamps. The terminals should be inspected to see if they have worked loose. If the trouble is not here, the leads are probably broken somewhere, and a cure will be effected by renewing the wire.

The batteries of cars which are not fitted with a charging device, require the same frequent inspection and attention as those with which we have dealt; and in addition, they must never be left in the car in a discharged condition longer than is absolutely unavoidable.

A battery that is not in use may be kept in condition for immediate service by charging it up about once a month. It is advisable to charge it fully just before putting it back into commission. The leads from a battery that is idle should be disconnected so that it cannot lose any charge due to leakage in the wiring system.

CHAPTER VII

A HOME CHARGING BOARD

HOW TO MAKE AND USE IT

THE efficient charging of an accumulator is one of the chief difficulties that many of us experience when using them; however much care we may take of our accumulators, they will not give good service unless they are regularly, and properly charged. Accumulators are charged by direct current (D.C.), and we shall deal in this chapter with the construction and use of a charging board suitable for use in houses which are supplied with D.C. If alternating current (A.C.) is supplied, the accumulators cannot be charged directly from it; the current must first be "rectified". Many suitable rectifiers are now available, but their construction and design are not within the scope of this book.

In order to charge our accumulators from a direct current supply, we have only to connect the accumulator terminals in series with the mains, and interpose a suitable resistance to reduce the current to the value required by the cell. Now the most convenient and reliable resistances which we can use for this purpose are ordinary lamps—either illuminating lamps or radiator lamps. The current which a lamp will pass can be calculated very easily. The rate at which energy is consumed by the lamp is always given when it is purchased; for instance, we speak of 20-watt lamps, 60-watt lamps and so on. Now the *Watt* is a unit of electric power, and the number of watts required to work a circuit is obtained by multiplying the E.M.F. (voltage) in the circuit, by the current. Therefore, if we have a lamp connected to 220-volt mains, and the current it takes is ½ ampère, we can calculate the "Wattage" thus:

Volts × Ampères = Watts.
Therefore: 220 × ½ = Watts.
= 110 watts.

The lamp must therefore be a 110-watt lamp.

Now we usually know the wattage of a lamp and the voltage of the mains, and we have to calculate the current from these. Suppose we have a 50-watt lamp on 200-volt mains, what current does it take? Well we have:

Volts × Ampères = Watts
Therefore: Ampères = Watts ÷ Volts
= 50 ÷ 200
= ¼

Thus our lamp will take ¼ ampère, and we have this rule: *To obtain the current taken by a lamp* (*or any electrical circuit*) *divide the Watts by the voltage of the supply.*

Now suppose we wish to pass a current of 1 ampère through an accumulator, all we have to do is to connect it in series with a lamp that takes 1 ampère, and connect to the mains, taking care to connect the positive terminal of the cell to the positive of the mains, and the negative to negative (see Fig. 15). If we have 220-volt mains, a suitable lamp for this purpose would be a 250-watt radiator lamp, which really would pass a little more than 1 ampère. We could get the same effect by connecting the battery in series with three lamps, each taking ⅓rd ampère and wired in parallel (Fig. 16). On a 220-volt supply, three 60-watt lamps would do. These would pass slightly less than 1 ampère. Two 100-watt lamps in parallel would also meet the case.

A charging board must be designed so that we can easily adjust the resistances, and so vary the current for the requirements of different accumulators.

We shall rarely want a current of more than about 5 ampères, so that we must design the board with this fact in mind as well.

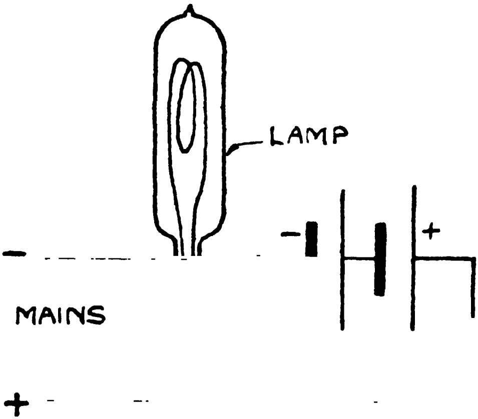

Fig. 15

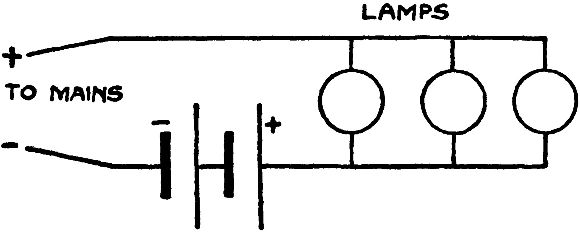

Fig. 16

We first require a board about 18 inches square and about 1 inch thick. This can be made by screwing two pieces of board, 9 in. × 18 in. side by side, on to two battens. In order to reduce the risk of fire to an absolute minimum, the surface of this board should be covered with sheet asbestos,

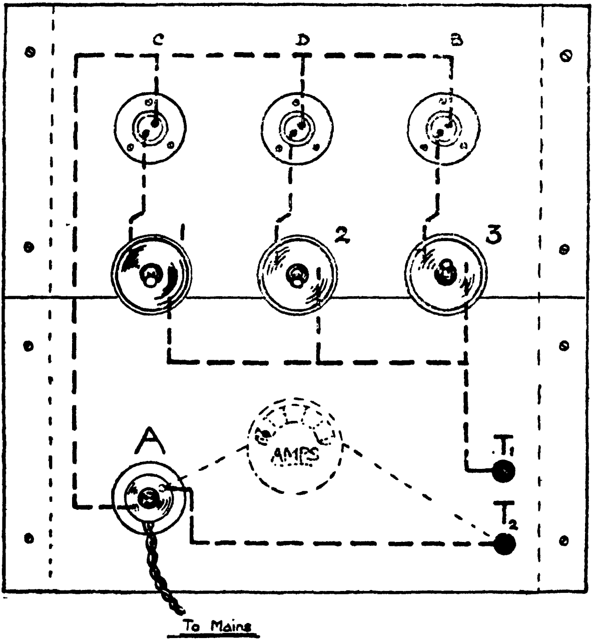

FIG. 17

SUGGESTED DESIGN FOR A CHARGING BOARD. THE WIRING IS INDICATED BY THE THICK DOTTED LINES. IF THE AMMETER IS INCLUDED IN THE DESIGN, NO WIRE FROM A TO T2 IS REQUIRED

although this is not absolutely necessary if the board is placed in a well ventilated position. Three batten-fitting, bayonet lamp holders are now screwed in a line parallel to the top edge of the board and about 4 inches from it; underneath these, three tumbler switches are fitted as shown in the diagram. In the bottom left hand corner of the board, a 5 or 10 ampère plug is fixed; and in the right hand bottom corner, two terminals, mounted at least 3 inches apart.

The wiring of the board can be followed easily from the diagram (Fig. 17).

The wire should be well insulated and capable of carrying 10 ampères. A single wire is first taken from the plug at A round to the last bayonet holder at B. This wire is tapped at C and D, and connections made to the other two holders, great care being taken to bind the joints with insulating tape. The next step is to wire each of the holders to a tumbler switch. Then a wire is connected to the other side of tumbler switch 1 and taken round to one of the terminals (T1), the other switches being wired up to this by taking tappings as before. The terminal T2 is connected to the unwired side of the plug at A.

As an additional safeguard, we may insert a fuse between A and C, wiring it with 5-ampère fuse wire. An ammeter may also be included in the circuit between A and T2—but this is something of a luxury, as the current can easily be calculated. If fitted, it should read up to 5 ampères.

The plug, to fit in the socket at A, must be wired up by means of a piece of heavy flex to another plug, or an adapter, so that it may be connected to the mains. The board should be connected to the power mains for cheapness.

Before using the board, the polarity of the terminals T1 and T2 must be known. The plug at A is inserted, and the other end of the flex is plugged into the mains. A lamp is next fitted in socket number 1, and switch 1 is pressed down. Two wires are then connected to T1 and T2 and their bared ends are placed so that they do not touch, in a glass of water. Bubbles of gas will then form on the negative wire, and the terminals can be marked. The plug at A and the mains plug must also be marked so that they can always be put back in the same way; if this is not done, the polarity of T1 and T2 must be determined before each charge.

In order to use the board, it is only necessary to fit lamps of the correct wattage in the sockets. We will suppose that the voltage of the mains is 220 and that we wish to charge an accumulator that requires a current of 2 ampères. The total wattage of the circuit must be: 2 × 220 = 440 watts. Thus lamps of which the total wattage is 440 must be plugged into the sockets. The following would meet the requirements:

1 250 Watt Radiator (heating) lamp,
2 100 Watt lamps.
Total: 450 watts.

If we have a small accumulator of which the charging current is ½ ampère, the total wattage required would be 220 × ½ = 110 watts. Thus one 100 watt lamp would suffice for this charge.

If high tension accumulators are to be charged from a board of this type, they should be separated into 10-volt units, and these units connected in parallel; that is, the positive terminals are connected together, and the negatives together. They can then be charged as one 10-volt accumulator (Fig. 18). If we have 10 such units, the charging current of this arrangement will be 10 times the charging current for one unit.

The reason for splitting up the battery in this way is that, if it is connected directly to the mains as a 100-volt unit, we cannot assume that the charging voltage is 220 volts. Actually it will only be about 120 volts, since the battery is connected in opposition to the mains. We get the same thing occurring with smaller accumulators, but the error in this case is not serious. For instance, by connecting a 10-volt accumulator to 220-volt mains, we only reduce the E.M.F. to 210 volts, which is so slight a variation that we need not bother about it.

The possession of a charging board is a great asset to those of us who wish to keep our accumulators in the very best condition. We may, however, be tempted to overcharge at first; this must be avoided if we want our plates to last. Should we undercharge the accumulator, or leave it for some time

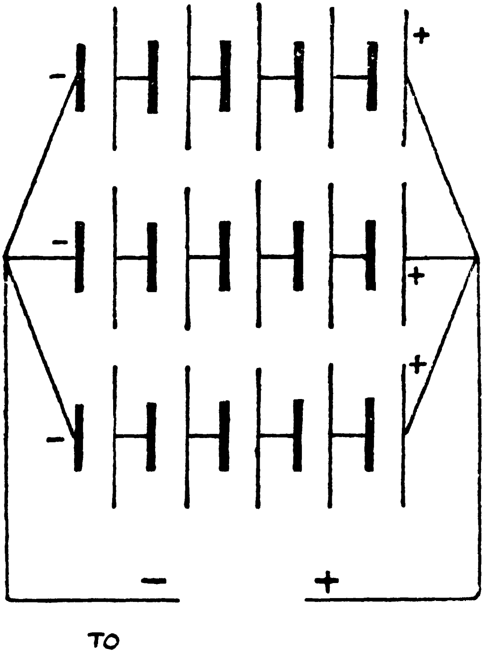

FIG. 18

THREE 10-VOLT ACCUMULATORS WIRED IN PARALLEL FOR CHARGING PURPOSES so that the plates become sulphated, we can restore it to good order again by prolonged charging at half normal rate. As soon as the cell begins to gas freely, the charging rate should be reduced to a quarter normal. If the cell is rested for an hour at intervals during this charge, the plates will gradually be restored to a healthy condition.

Summary of Instructions for Charging

1. Remove vent plugs, and do not replace them until the end of the charge.

2. Add distilled water, if necessary, at beginning of change.

3. Keep naked flames away from the cell, and see that the temperature of the cell itself does not rise above 100° F.

4. Do not overcharge.

GLOSSARY OF TERMS

Ammeter—An instrument for reading off directly the value of a current in ampères.

Ampère—The practical unit of electric current.

Ampère-Hour—A unit of electric quantity. It is the amount of electricity which passes through a circuit when a current of 1 ampère flows for 1 hour.

Bus-Bars—Bars to which the plates of a cell are welded.

Capacity—The amount of electricity, expressed in ampère-hours, that a cell is capable of storing.

Distilled Water—Water which is obtained by condensing steam.

Electric Potential—Electric pressure.

Electrolyte—The fluid in a cell.

E.M.F.—Electro-motive force. The difference of potential between the plates of a cell, or the terminals of a dynamo measured in volts.

Gassing—Evolution of gas at the plates of a cell.

Hydrometer—An instrument for determining the specific gravity of a liquid.

Internal Resistance—The resistance of a cell, measured across its terminals.

Open Circuit—An incomplete circuit.

Parallel—Cells are connected in parallel when their positive terminals are connected together, and their negatives are also connected. If 3 cells of 2 volts each are connected in parallel, the result is equivalent to 1 cell of 2 volts, but of a capacity equal to the sum of the capacities of the 3 cells.

Resistance—The property of a conductor which impedes the passage of a current through it. Resistance is measured in OHMS.

Series—Cells connected so that the positive of one cell is connected to the negative of the next, and so on, are said to be connected in series. If three 2-volt cells are connected in series, we get a battery of E.M.F. 6 volts, and with a capacity equal to that of the smallest cell.

Short Circuit—Direct contact between the plates or terminals of a cell or battery.

Specific Gravity—The ratio of the weight of a certain volume of substance to the weight of the same volume of water.

Topping Up—Adding water or acid to a cell to restore the level of the electrolyte to its normal height.

Volt—The unit of electric pressure, or potential.

Voltmeter—An instrument for measuring the difference of electric potential between two points.

Watt—Unit of electric power. The wattage for any circuit = volts × ampères.

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